TRANSLATOR'S VERIFICATION

I hereby declare and state that I am knowledgeable of each of the Japanese and English languages and that I made and reviewed the attached translation of the certified copy of Japanese Patent Application No. 2002-294716, filed on October 8, 2002 from the Japanese language into the English language, and that I believe my attached translation to be accurate, true and correct to the best of my knowledge and ability.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of this application or any patent issued thereon.

Date: September 16, 2004

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JAPAN PATENT OFFICE

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Date of Application:	October 8, 2002
Application Number:	2002-294716
[ST. 10/C]:	[JP2002-294716]
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July 9, 2003
Commissioner, Japan Patent Office
Shinichiro OTA

Certificate Issuance No. 2003-3054439

[Title of the Document] Patent Application

[Reference Number] HM0242

[Filing Date] October 8, 2002

[Attention] To Commissioner, Patent Office

[IPC] G11B 5/00

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[Indication of charge]

[Serial number for pre-paid] 057521

[Amount of payment] 21,000yen

[List of filing documents]

[Name of Document] Specification 1

[Name of Document] Drawing 1

[Name of Document] Abstract 1

[Serial Number of General Power of Attorney] 0112006

[Necessity of the proof] yes

[TITLE OF THE DOCUMENT] Specification

[TITLE OF THE INVENTION] MAGNETIC RECORDING MEDIUM AND MAGNETIC RECORDING APPARATUS

[CLAIMS]

[Claim 1] A magnetic recording medium comprising:

an underlayer which is formed of an alloy mainly composed of CoCrRu; and

a recording layer which is formed on the underlayer and which is composed of a CoPtCr alloy magnetic material containing oxygen.

[Claim 2] The magnetic recording medium according to claim 1, characterized in that the underlayer has a film thickness of 5 to 20 nm.

[Claim 3] The magnetic recording medium according to claim 1 or 2, characterized in that Co is contained by 1 to 65 at. % in the underlayer formed of the alloy mainly composed of CoCrRu.

[Claim 4] The magnetic recording medium according to any one of claims 1 to 3, characterized in that underlayer, which is formed of the alloy mainly composed of CoCrRu, contains at least one element selected from the group consisting of Rh, Ir, Hf, Cu, Ag, Au, Re, Mo, Nb, W, Ta, Ti, V, Zr, Pt, Pd, B, and C.

[Claim 5] The magnetic recording medium according to any one of claims 1 to 4, characterized by further comprising a non-magnetic substrate which is provided on a

surface of a side opposite to a side of the underlayer on which the recording layer is formed.

[Claim 6] The magnetic recording medium according to claim 5, characterized by further comprising a soft magnetic back layer which is formed of a soft magnetic material between the underlayer and the substrate.

[Claim 7] The magnetic recording medium according to claim 6, characterized in that the soft magnetic back layer has a film thickness of 50 to 500 nm.

[Claim 8] The magnetic recording medium according to claim 5, characterized by further comprising an intermediate layer which is formed of Ti or Ta or formed of an alloy mainly containing Ti or Ta between the underlayer and the substrate.

[Claim 9] The magnetic recording medium according to claim 8, characterized in that the intermediate layer has a film thickness of 2 to 20 nm.

[Claim 10] The magnetic recording medium according to claim 8 or 9, characterized by further comprising a soft magnetic back layer which is formed of a soft magnetic material between the intermediate layer and the substrate.

[Claim 11] The magnetic recording medium according to claim 10, characterized in that the soft magnetic back layer has a film thickness of 50 to 500 nm.

[Claim 12] The magnetic recording medium according to any one of claims 1 to 11, characterized in that an oxygen

content of the recording layer is 5 to 20 at. %.

[Claim 13] The magnetic recording medium according to any one of claims 1 to 12, characterized in that Si or Mg is contained by 3 to 15 at. % in the recording layer.

[Claim 14] The magnetic recording medium according to any one of claims 1 to 13, characterized in that in a rocking curve of a CoCrPtO (002) peak obtained with measurement of X-ray diffraction on a surface of the recording layer, a half value width of the rocking curve is not more than 6 degrees.

[Claim 15] A magnetic recording apparatus comprising:

the magnetic recording medium according to claim 1;

a magnetic head for recording or reproducing information on the magnetic recording medium; and

a driving unit for driving the magnetic recording medium with respect to the magnetic head.

[0001]

[TECHNICAL FIELD TO WHICH THE INVENTION BELONGS]

The present invention relates to a magnetic recording medium and a magnetic recording apparatus. In particular, the present invention relates to a magnetic recording medium based on the perpendicular magnetic recording system suitable for the high density recording, and a magnetic recording apparatus.

[0002]

[PRIOR ART]

In recent years, as the information oriented society is advanced, it becomes possible to process, for example, not only the character information but also the voice information and the image information at high speeds. One of the apparatuses capable of processing the information as described above at the high speed is a magnetic recording apparatus which is installed, for example, to a computer. The magnetic recording apparatus is being developed in order to realize a further small size while improving the recording density.

[0003]

In general, the magnetic recording apparatus includes a plurality of magnetic disks which are rotatably installed on a spindle. Each of the magnetic disks includes a substrate and a magnetic film (appropriately referred to as "recording layer" as well) which is formed on the substrate. Information is recorded by forming magnetic domains having specified directions of magnetization in the magnetic film. Conventionally, the direction of magnetization subjected to the recording in the magnetic film is the in-plane direction of the magnetic film. This system is called "in-plane recording system". The realization of the high density recording on the magnetic disk based on the in-plane recording system can be achieved by thinning the film thickness of the magnetic film, providing minute grain diameters of magnetic crystal grains

which constitute the magnetic film, and reducing the magnetic interaction between the respective magnetic crystal grains. However, when the magnetic crystal grains are made to be fine and minute and the magnetic interaction between the magnetic crystal grains is reduced, then the thermal stability of the recorded magnetization is deteriorated. In order to solve this problem, a magnetic disk based on the perpendicular recording system has been suggested.

[0004]

In the perpendicular recording system, the direction of magnetization of the magnetic domain in the magnetic film is perpendicular to the film surface to perform the recording. When this system is used, then the interstice between the adjoining recording bits is magnetostatically stabilized, the thermal stability is improved, and the recording transition area becomes sharp. Further, when a layer formed of a soft magnetic material (hereinafter referred to as "soft magnetic back layer") is added between the substrate and the recording layer of the magnetic disk based on the perpendicular recording system, then the magnetic field, which is applied to the recording layer during the recording of information, can be converged, and it is possible to perform the recording on a magnetic material having higher magnetic anisotropy. It is possible to perform the recording at higher recording densities,

because the magnetization of the magnetic material having the high magnetic anisotropy has high thermal stability.

[0005]

A CoCr-based alloy is used for the recording layer of the magnetic disk based on the in-plane recording system described above. It is tried to similarly apply the CoCr-based alloy to the recording layer of the magnetic disk based on the perpendicular recording system as well. A two-phase separation structure, which is composed of the ferromagnetic crystal grains having a high Co concentration and the non-magnetic crystal grain boundary having a high Cr concentration, is formed in the recording layer formed of the CoCr-based alloy. The magnetic interaction between the ferromagnetic crystal grains can be shut off by the non-magnetic crystal grain boundary. Accordingly, the low noise of the medium, which is required for the high density recording, has been hitherto realized.

[0006]

However, in order to realize the recording at higher densities, it is necessary to further reduce the magnetic interaction between the crystal grains. There is a method for solving this problem, in which the crystal grain boundary is oxidized in the recording layer composed of the CoCr-based alloy by adding oxygen to the recording layer. Such a method is carried out by adding an oxide to a sputtering target, or by forming a film of the recording

layer in an oxygen gas atmosphere. A medium, which includes the recording layer composed of the CoCr-based oxide obtained by such a method, has an oxide granular structure in which the magnetic crystal grains of the recording layer are surrounded by the oxide. The magnetic interaction between the magnetic crystal grains is further reduced by the oxide granular structure, and it is possible to further reduce the medium noise of the magnetic recording medium.

[0007]

When the medium, which includes the recording layer composed of the CoCr-based oxide, is manufactured, it is necessary that the crystalline orientation of the recording layer is controlled so that the easy axis of magnetization of the recording layer formed of the CoCr-based oxide is directed in the direction perpendicular to the film surface. For this purpose, an underlayer or underlying base layer is used. The crystalline structure of the CoCr-based oxide is the hcp (hexagonal close-packed lattice) structure, and the easy axis of magnetization thereof resides in the c-axis direction. Therefore, in order that the c-axis of the CoCr-based oxide is oriented in the direction perpendicular to the film surface, it is necessary to provide the underlayer which has the same hcp structure as that of the CoCr-based oxide. The element, which has the same hcp structure as that of the crystalline

structure of the CoCr-based oxide, includes Ti, Ru, and alloys thereof. An exemplary magnetic recording medium, which has an underlayer formed of such an element, has been suggested. In this magnetic recording medium, a CoPtCrO magnetic layer is used for a recording layer, and Ru is used for the underlayer (for example, see Patent Document 1).

[0008]

[Patent Document 1] Japanese Patent Application Laid-open No. 2001-6158 (p. 3, Fig. 1)

[0009]

[PROBLEM TO BE SOLVED BY THE INVENTION]

In the magnetic recording medium in which an underlayer is provided in order to improve the crystalline orientation of the recording layer composed of the CoCr-based oxide, a soft magnetic back layer is also provided between the underlayer and the substrate in order to improve the recording characteristics. Therefore, when the film thickness of the underlayer is thickened, a problem arises such that the distance between the soft magnetic back layer and the recording layer is increased, thereby deteriorating the recording characteristics. Accordingly, in a medium having the CoCr-based oxide as the recording layer, an underlayer is required which films thickness is thin and which increases the orientation of the recording layer, so that the deterioration of the recording

characteristics is suppressed and the higher density recording is realized.

[0010]

An object of the present invention is to provide a magnetic recording medium which solves the problem involved in the conventional technique as described above, which is based on the perpendicular recording system including a recording layer composed of CoCr-based oxide, and which has a thin film thickness of an underlayer, wherein the orientation of the recording layer is high, and thus the coercivity is high with low medium noise.

[0011]

[MEANS FOR SOLVING THE PROBLEM]

According to a first aspect of the present invention, there is provided a magnetic recording medium comprising an underlayer which is formed of an alloy mainly composed of CoCrRu; and a recording layer which is formed on the underlayer and which is composed of a CoPtCr alloy magnetic material containing oxygen.

[0012]

The inventors manufactured magnetic recording media having underlayers formed of Ti, Ru, and alloy thereof having the same hcp structure as that of the CoPtCr alloy magnetic film containing oxygen for forming the recording layers to evaluate magnetic characteristics and recording and reproduction characteristics thereof. As a result, the

following fact was revealed. That is, the crystalline orientation of the recording layer was successfully controlled by using the underlayer formed of Ti, Ru, and alloy thereof. However, in order to successfully effect the control, it was necessary that the film thickness of the underlayer exceeded 50 nm, which resulted in the deterioration of the recording characteristics. On the other hand, in the case of the thin film thickness of not more than 50 nm, the crystallinity of the recording layer was deteriorated, and it was unsuccessful to perform any sufficient high density recording.

[0013]

In the magnetic recording medium of the present invention, the CoCrRu film, in which Ru is mixed with the non-magnetic CoCr alloy, is used as the underlayer for the recording layer which is formed of the CoPtCr alloy magnetic film containing oxygen. The crystalline structure of the CoCrRu film used for the underlayer is the same hcp structure as that of the CoPtCr alloy magnetic film containing oxygen used for the recording layer. When the CoCrRu film is used as the underlayer for the recording layer, the c-axis, which is the easy axis of magnetization of the CoPtCr alloy magnetic film containing oxygen, can be subjected to the crystalline orientation in the direction perpendicular to the in-plane of the recording layer, even when the film thickness of the underlayer is thin, i.e.,

not more than 50 nm. Accordingly, it is possible to enhance the crystalline orientation of the recording layer formed of the CoPtCr alloy magnetic film containing oxygen, and it is possible to improve the static magnetic characteristics. Further, it is also possible to avoid the deterioration of the recording characteristics, because the film thickness of the underlayer is thin. The recording layer has such a structure that the magnetic crystal grains are surrounded by oxide, because the recording layer is formed of the CoPtCr alloy magnetic film containing oxygen. The magnetic interaction between the crystal grains is reduced in the recording layer. That is, according to the present invention, it is possible to provide the magnetic recording medium which has the high coercivity, which has the lower medium noise, and which makes it possible to perform the recording at the high recording density.

[0014]

In the magnetic recording medium of the present invention, it is preferable that the underlayer, which is formed of the alloy mainly composed of CoCrRu, has a film thickness of 5 to 20 nm. When the film thickness of the underlayer is less than 5 nm, the crystalline orientation of the recording layer formed on the underlayer is deteriorated. When the film thickness of the underlayer is more than 20 nm, then the crystal grains of the underlayer become coarse, which causes not only the increase in medium

noise but also the increase in the distance between the recording layer and the soft magnetic back layer as described later on. Thus, the recording characteristics are deteriorated.

[0015]

It is preferable that the underlayer, which is formed of the alloy mainly composed of CoCrRu, is non-magnetic. In the underlayer, it is preferable that the composition ratio of Co is 1 to 65 at. %. When the Co concentration of the underlayer becomes greater than this value, the underlayer ceased to be non-magnetic, and it is possible that ill effects are exerted on the information recording and reproduction characteristics.

[0016]

In the magnetic recording medium of the present invention, it is preferable that the underlayer, which is formed of the alloy mainly composed of CoCrRu, contains at least one element selected from the group consisting of Rh, Ir, Hf, Cu, Ag, Au, Re, Mo, Nb, W, Ta, Ti, V, Zr, Pt, Pd, B and C. Accordingly, the lattice match is improved between the CoCrRu film of the underlayer and the CoPtCr alloy magnetic film containing oxygen formed as the recording layer thereon.

[0017] In the magnetic recording medium of the present invention, it is preferable that a non-magnetic substrate is provided on a surface of a side opposite to a side of

the underlayer on which the recording layer is formed. It is preferable that a soft magnetic back layer, which is formed of a soft magnetic material, is provided between the underlayer and the substrate. The soft magnetic back layer has such a role that the magnetic flux leaked from the magnetic head is converged on the recording layer when information is recorded/reproduced in the recording layer by using the magnetic head. As for the material for the soft magnetic back layer, it is preferable to use a soft magnetic material which has large saturation magnetization, which has small coercivity, and which has high magnetic permeability. For example, it is preferable to use a CoTaZr film. It is desirable that the film thickness of the soft magnetic back layer is within a range of 50 to 500 nm.

[0018]

In the magnetic recording medium of the present invention, it is preferable that an intermediate layer, which is formed of Ti or Ta, or formed of an alloy mainly containing Ti or Ta, is provided between the underlayer and the substrate. It is preferable that the film thickness of the intermediate layer formed of these materials is 2 to 20 nm. By providing the intermediate layer formed of Ti or Ta, or formed of an alloy mainly containing Ti or Ta, it is possible to further enhance the crystalline orientation of the recording layer formed of the CoPtCr alloy magnetic

film containing oxygen, and to further increase the static magnetic characteristics of the recording layer. Further, it is preferable that a soft magnetic back layer, which is formed of the soft magnetic material and has the film thickness of 50 to 500 nm, is provided between the intermediate layer and the substrate.

[0019]

In the magnetic recording medium of the present invention, it is preferable that the oxygen content of the CoPtCr alloy magnetic film containing oxygen for forming the recording layer is 5 to 20 at. %. The CoPtCr alloy magnetic film containing oxygen is formed by using a mixed gas of argon and oxygen as the sputtering gas. When the mixing ratio therebetween is appropriately regulated, it is possible to introduce 5 to 20 at. % oxygen in a dispersed state into the CoPtCr alloy magnetic film. Alternatively, the oxygen content in the CoPtCr alloy magnetic film can be also changed by regulating the amount of oxygen contained in the target. For example, it is possible to use a target obtained by mixing SiO_2 or MgO at a ratio of several % to several tens % in the CoPtCr target. When the CoPtCr alloy magnetic film, which contains 5 to 20 at. % oxygen, is used, then it is possible to reduce the magnetic interaction between the magnetic crystal grains, and it is possible to provide the medium having low medium noise. When the oxygen content in the CoPtCr alloy magnetic film

is less than 5 at. %, then the magnetic grains are insufficiently separated from each other, and the reduction of the medium noise is also insufficient. On the other hand, when the oxygen content in the CoPtCr alloy magnetic film is more than 20 at. %, the oxygen is incorporated into the magnetic crystal grains, thereby deteriorating the magnetic characteristics.

[0020]

The inventors manufactured magnetic recording media having recording layers formed of CoPtCr alloy magnetic films containing 5 to 20 at. % oxygen to verify the oxygen contents in the CoPtCr alloy magnetic films. At first, as a result of the EDX measurement with plane TEM, it has been revealed that the oxygen contained in the CoPtCr alloy magnetic film preferentially oxidizes Cr to give a form of Cr oxide which surrounds the Co magnetic grains and which exists between the grains. Further, it has been revealed that the crystal grains of the recording layer are made fine and minute by introducing the oxygen into the CoPtCr alloy magnetic film. It is considered that the magnetic interaction between the crystal grains is reduced by the fine and minute crystal grains of the recording layer and the Co magnetic grains surrounded by the Cr oxide, and thus the medium noise of the magnetic recording medium can be reduced.

[0021]

Further, a magnetic recording medium having a recording layer formed with a CoPtCr alloy magnetic film containing no oxygen was manufactured to measure the signal-to-noise ratio (S/N ratio) which was compared with the S/N ratios of the magnetic recording media having recording layers formed of CoPtCr alloy magnetic films containing 5 to 20 at. % oxygen. As a result, the S/N ratio of the magnetic recording medium composed of the CoPtCr alloy magnetic film mixed with oxygen was improved by 12 dB as compared with the S/N ratio of the magnetic recording medium composed of the CoPtCr alloy magnetic film containing no oxygen. If the oxygen content of CoPtCr alloy magnetic film is less than 5 at. %, then the magnetic interaction between the crystal grains is intensified, and the S/N ratio is deteriorated. If the oxygen content of the CoPtCr alloy magnetic film is more than 20 at. %, the S/N ratio was deteriorated due to the deterioration of the magnetic characteristics. According to the verification as described above, it has been revealed that the content of oxygen contained in the CoPtCr alloy magnetic film is preferably 5 to 20 at. % in order to provide the medium having the low medium noise by further reducing the magnetic interaction between the crystal grains.

[0022]

In the magnetic recording medium of the present invention, it is preferable that Si or Mg is contained by 3

to 15 at. % in the CoPtCr alloy magnetic film containing oxygen. When Si or Mg is mixed at the content of 3 to 15 at. % in the CoCrPt alloy magnetic film containing oxygen, then it is possible to improve the coercivity of the magnetic recording medium, and it is possible to realize the low noise of the medium. The method for mixing Si or Mg in the CoPtCr alloy magnetic film containing oxygen includes a method in which the sputtering is performed by using a target which is mixed with SiO_2 or MgO at a ratio of several % to several tens % in the CoPtCr target. In this method, it is possible to adjust not only the content of Si or Mg but also the content of oxygen. The formed CoCrPt alloy magnetic film has such a structure that SiO_2 or MgO exists around the Co magnetic crystal grains.

[0023]

According to a second aspect of the present invention, there is provided a magnetic recording apparatus comprising the magnetic recording medium of the present invention; a magnetic head for recording or reproducing information on the magnetic recording medium; and a driving unit for driving the magnetic recording medium with respect to the magnetic head.

[0024]

[EMBODIMENT OF THE INVENTION]

The magnetic recording medium and the magnetic recording apparatus according to the present invention will

be specifically explained below as exemplified by embodiments. However, the present invention is not limited thereto.

[0025]

[First Embodiment]

Fig. 1 shows a schematic sectional view illustrating a magnetic disk manufactured in a first embodiment. As shown in Fig. 1, the magnetic disk 10 has such a structure that an adhesive layer 2, a soft magnetic back layer 3, an underlayer 4, a recording layer 5, and a protective layer 6 are successively stacked or laminated on a substrate 1. The adhesive layer 2 is provided in order to avoid any exfoliation between the substrate 1 and the films stacked thereon. The soft magnetic back layer 3 is provided in order to converge the magnetic field to be applied to the recording layer when information is recorded. The underlayer 4 is provided in order to improve the orientation of the recording layer 5. The recording layer 5 is the layer in which information is recorded as magnetization information. The direction of magnetization of the recording layer 5 is in the direction perpendicular to the film surface. The protective layer 6 is provided in order to protect the stacked films 2 to 5 which are successively stacked on the substrate 1. An explanation will be made below about a method for manufacturing the magnetic disk manufactured in this embodiment.

[0026]

A circular disk-shaped glass substrate having a diameter of 2.5 inches (6.25 cm) was used for the substrate 1. The substrate 1 was heated to 260 °C before the film formation. A Ti film was formed as the adhesive layer 2 on the substrate 1 with the DC sputtering. The sputtering condition was as follows. That is, the gas pressure was 0.28 Pa, the input electric power was 500 W, and the target was Ti. The film thickness of the adhesive layer 2 was 5 nm.

[0027]

Subsequently, a CoTaZr film was formed as the soft magnetic back layer 3 on the adhesive layer 2 with the DC sputtering. The sputtering condition was as follows. That is, the gas pressure was 0.28 Pa and the input electric power was 400 W. The target had a composition of $Co_{88}Ta_{10}Zr_2$ (at. %). The film thickness of the soft magnetic back layer 3 was 200 nm.

[0028]

Subsequently, a CoCrRu film was formed as the under layer 4 on the soft magnetic back layer 3 with the DC sputtering. The sputtering condition was as follows. That is, the gas pressure was 4.2 Pa and the input electric power was 500 W. The target had a composition of $Co_{55}Cr_{25}Ru_{20}$ (at. %). The film thickness of the underlayer 4 was 20 nm.

[0029]

Further, a CoPtCr alloy magnetic film containing oxygen was formed as the recording layer 5 on the underlayer 4 with the RF sputtering. The sputtering condition was as follows. That is, the gas pressure was 4.2 Pa and the input electric power was 400 W. The target had a composition of $Co_{64}Pt_{20}Cr_{16}$ (at. %)-O (CoPtCr: O = 90:10 mol %). The film thickness of the recording layer 5 was 24 nm.

[0030]

Finally, a C film was formed as the protective layer 6 on the recording layer 5 with the DC sputtering. The sputtering condition was as follows. That is, the gas pressure was 0.20 Pa and the input electric power was 300 W. The film thickness of the protective layer 6 was 10 nm.

[0031]

In this embodiment, the film thickness of the CoCrRu film of the underlayer 4 was changed within a range of 10 to 30 nm to manufacture a variety of magnetic disks 10 in accordance with the same manufacturing method as that used in the process described above. The coercivities of the respective magnetic disks were measured in the in-plane direction and in the direction perpendicular to the film surface respectively. Fig. 2 shows the changes of the perpendicular coercivity $Hc_{\perp}$ and the in-plane coercivity $Hc_{\parallel}$ with respect to the film thickness of the CoCrRu film

of the underlayer. However, for the purpose of comparison, the coercivity of a magnetic disk having a film thickness of the CoCrRu film of the underlayer of 0 nm, i.e., a magnetic disk provided with no underlayer is also plotted in Fig. 2. As shown in Fig. 2, it has been revealed that the perpendicular coercivity $Hc_{\perp}$ is increased by providing the CoCrRu film as the underlayer for the recording layer, and the perpendicular coercivity $Hc_{\perp}$ is increased as the film thickness of the CoCrRu film is increased. On the other hand, as shown in Fig. 2, the in-plane coercivity $Hc_{\parallel}$ was decreased as the film thickness of the CoCrRu film was increased. It is considered that the c-axis orientation of the recording layer is improved by the effect of the CoCrRu film provided as the underlayer for the recording layer.

[0032]

The X-ray diffraction measurement was performed for the surface of the magnetic disk manufactured in this embodiment. An obtained result is shown in Fig. 3. However, the result shown in Fig. 3 was obtained when the film thickness of the CoCrRu film of the underlayer was 20 nm. As a result, the following fact has been revealed as shown in an X-ray diffraction intensity distribution shown in Fig. 3(a). That is, peaks corresponding to CoCrRu (002) and CoCrPtO (002) are clearly observed. The c-axis, which is the easy axis of magnetization of the CoPtCr alloy magnetic film containing oxygen formed as the recording

layer, is oriented in the direction perpendicular to the film surface. Further, Fig. 3(b) shows a rocking curve measured at the peak of CoCrPtO (002). The half value width $\Delta\theta_{50}$ of the rocking curve was 5.8°.

[0033]

Subsequently, a lubricant was applied on the protective layer of the magnetic disk manufactured in this embodiment. After that, the magnetic disks as described above were installed into a magnetic recording apparatus 60 shown in Fig. 4 to evaluate the recording and reproduction characteristics.

[0034]

Fig. 4 shows a schematic arrangement of the magnetic recording apparatus. Fig. 4(a) shows a schematic plan view of the magnetic recording apparatus 60, and Fig. 4(b) shows a schematic sectional view of the magnetic recording apparatus 60 taken along a broken line A-A' shown in Fig. 4(a). As shown in Fig. 4(b), the magnetic disks 10 are coaxially attached to a spindle 52 of a rotary driving system 51, and they are rotated by the spindle 52.

[0035]

When information was recorded on the magnetic disk 10 by using the magnetic recording apparatus 60, a thin film magnetic head, which was based on the use of a soft magnetic film having a high saturation magnetic flux density of 2.1 T, was used. When information was

reproduced, a spin-valve type magnetic head having the giant magnetoresistance effect was used. The thin film magnetic head for the recording and the spin-valve type magnetic head for the reproduction are integrated into one unit which is indicated by a magnetic head 53 in Fig. 4. The integrated type magnetic head 53 is controlled by a magnetic head driving system 54. The distance between the magnetic disk surface and the magnetic head surface of the magnetic recording apparatus 60 was maintained to be 10 nm.

[0036]

A signal corresponding to a recording density of 700 kfci was recorded on the magnetic disk 10 to evaluate the recording and reproduction characteristic (S/N ratio) of the magnetic disk. However, this test was performed for the magnetic disk in which the film thickness of the CoCrRu film of the underlayer was 20 nm. As a result, there was obtained S/N ratio = 25 dB.

[0037]

[Second Embodiment]

Fig. 5 shows a schematic sectional view of a magnetic disk manufactured in a second embodiment. As shown in Fig. 5, the magnetic disk 50 manufactured in this embodiment has such a structure that an adhesive layer 2, a soft magnetic back layer 3, an intermediate layer 7, an underlayer 4, a recording layer 5, and a protective layer 6 are successively stacked or laminated on a substrate 1. The

intermediate layer 7 is provided in order to further improve the crystalline orientation of the recording layer 5. An explanation will be made below about a method for manufacturing the magnetic disk 50 manufactured in this embodiment.

[0038]

At first, a circular disk-shaped glass substrate having a diameter of 2.5 inches (6.25 cm) was used for the substrate 1. A Ti film was formed as the adhesive layer 2 on the substrate 1 with the DC sputtering. The sputtering condition was as follows. That is, the gas pressure was 0.28 Pa, the input electric power was 500 W, and the target was Ti. The film thickness of the adhesive layer 2 was 5 nm.

[0039]

Subsequently, a CoTaZr film was formed as the soft magnetic back layer 3 on the adhesive layer 2 with the DC sputtering. The sputtering condition was as follows. That is, the gas pressure was 0.28 Pa and the input electric power was 500 W. The target had a composition of $Co_{88}Ta_{10}Zr_2$ (at. %). The film thickness of the soft magnetic back layer 3 was 200 nm.

[0040]

Subsequently, a Ti film was formed as the intermediate layer 7 on the soft magnetic back layer 3 with the DC sputtering. The sputtering condition was as follows. That

is, the gas pressure was 0.28 Pa, the input electric power was 500 W, and the target was Ti. The film thickness of the intermediate layer 7 was 10 nm.

[0041]

Subsequently, a CoCrRu film was formed as the underlayer 4 on the intermediate layer 7 with the DC sputtering. The sputtering condition was as follows. That is, the gas pressure was 0.28 Pa and the input electric power was 500 W. The target had a composition of $Co_{55}Cr_{25}Ru_{20}$ (at. %). The film thickness of the underlayer 4 was 20 nm.

[0042]

Further, a CoPtCr alloy magnetic film containing oxygen was formed as the recording layer 5 on the underlayer 4 with the RF sputtering. The sputtering condition was as follows. That is, the gas pressure was 4.2 Pa and the input electric power was 400 W. The target had a composition of $Co_{64}Pt_{20}Cr_{16}$ (at. %)-O (CoPtCr:O = 90:10 mol %). The film thickness of the recording layer 5 was 24 nm.

[0043]

Finally, a C film was formed as the protective layer 6 on the recording layer 5 with the DC sputtering. The sputtering condition was as follows. That is, the gas pressure was 0.20 Pa and the input electric power was 300 W. The film thickness of the protective layer 6 was 5 nm.

[0044]

In this embodiment, the film thickness of the Ti film of the intermediate layer 7 was changed within a range of 5 to 25 nm to manufacture a variety of magnetic disks 50 in accordance with the same manufacturing method as that used in the process described above. The coercivities of the respective magnetic disks were measured in the direction perpendicular to the film surface. Fig. 6 shows the change of the perpendicular coercivity $Hc_{\perp}$ with respect to the film thickness of the Ti film of the intermediate layer. However, the result shown in Fig. 6 was obtained when the film thickness of the CoCrRu film of the underlayer was 20 nm. Further, for the purpose of comparison, the perpendicular coercivity $Hc_{\perp}$ of a magnetic disk (magnetic disk of the type of the first embodiment) having a film thickness of the Ti film of the intermediate layer of 0 nm, i.e., a magnetic disk provided with no intermediate layer is also plotted in Fig. 6. As shown in Fig. 6, it is revealed that by providing the Ti film as the intermediate layer between the underlayer and the soft magnetic back layer, the perpendicular coercivity $Hc_{\perp}$ is increased, and the perpendicular coercivity $Hc_{\perp}$ is increased as the thickness of the Ti film is increased. Accordingly, by providing the Ti film as the intermediate layer between the underlayer and the soft magnetic back layer, the perpendicular coercivity $Hc_{\perp}$ of the magnetic disks

manufactured in this embodiment is improved than the perpendicular coercivity $Hc_{\perp}$ of the magnetic disks manufactured in the first embodiment.

[0045]

The X-ray diffraction measurement was also performed for the magnetic disks manufactured in this example in a similar manner as in the first embodiment. However, in the magnetic disks used for the measurement, the film thickness of the CoCrRu film of the underlayer was 20 nm, and the film thickness of the Ti film of the intermediate layer was 10 nm. With respect to the magnetic disks manufactured in this example, a half value width $\Delta\theta_{50}$ of a rocking curve of the peak of CoCrPtO (002) was measured. As a result, the half value width $\Delta\theta_{50}$ was 4.0°, which is smaller than the half value width $\Delta\theta_{50}$ (5.8°) of the magnetic disks manufactured in the first embodiment. Accordingly, the following fact was revealed. That is, by providing the Ti film as the intermediate layer between the underlayer and the soft magnetic back layer, the crystalline orientation of the recording layer formed of the CoPtCr alloy magnetic film containing oxygen is further enhanced.

[0046]

Further, in this example, the film thickness of the CoCrRu film of the underlayer was changed within a range of 5 to 40 nm to manufacture a variety of magnetic disks to

measure a half value width $\Delta\theta_{50}$ of a rocking curve of the peak of CoCrPtO (002) of the respective magnetic disks. However, the film thickness of the Ti film of the intermediate layer was fixed to be 10 nm. Fig. 7 shows the change of the half value width $\Delta\theta_{50}$ of the peak of CoCrPtO (002) with respect to the film thickness of the CoCrRu film of the underlayer in the magnetic disks manufactured in this example. As shown in Fig. 7, the following fact was revealed. That is, as the film thickness of the CoCrRu film is increased, the half value width $\Delta\theta_{50}$ is decreased, and the crystalline orientation of the recording layer is enhanced. However, when the film thickness of the underlayer is too thick, the grain diameters of magnetic crystal grains of the underlayer become coarse, and the distance between the recording layer and the soft magnetic back layer becomes greater, thereby deteriorating the recording characteristics. Thus, it cannot be expected to improve the recording and reproduction characteristics. Accordingly, it is preferable that the film thickness of the CoCrRu film is 5 to 20 nm.

[0047]

Subsequently, the magnetic disks manufactured in this example were installed into the magnetic recording apparatus 60 shown in Fig. 4 to evaluate the recording and reproduction characteristics in the same manner as in the first embodiment. However, this test was carried out for

the magnetic disks in each of which the film thickness of the CoCrRu film of the underlayer was 20 nm and the film thickness of the Ti film of the intermediate layer was 10 nm. As a result, there was obtained S/N ratio = 27 dB. The recording and reproduction characteristic was improved as compared with the S/N ratio (25 dB) of the magnetic disk manufactured in the first embodiment. According to this result, it has been revealed that by providing the intermediate layer formed of the Ti film between the underlayer and the soft magnetic back layer, the S/N ratio is further improved.

[0048]

[Comparative Example]

In Comparative Example, a magnetic disk was manufactured in the same manner as in the first embodiment except that an underlayer of the magnetic disk was formed of an Ru film in place of the CoCrRu film. The Ru film was formed on the soft magnetic back layer with the DC sputtering. The sputtering condition was as follows. That is, the gas pressure was 0.28 Pa, the input electric power was 500 W, and the target was Ru. The film thickness of the Ru film was 20 nm.

[0049]

The X-ray diffraction measurement was performed for the magnetic disk manufactured in Comparative Example in the same manner as in the first embodiment. Table 1 shows

the half value widths $\Delta\theta_{50}$ of the rocking curves of the peaks of CoCrPtO (002) of the magnetic disks manufactured in the first and second embodiments and Comparative Example. However, in Table 1, the value of the half value width $\Delta\theta_{50}$ of the first embodiment resides in the result obtained when the film thickness of the CoCrRu film of the underlayer was 20 nm. The value of the half value width $\Delta\theta_{50}$ of the second embodiment resides in the result obtained when the film thickness of the CoCrRu film of the underlayer was 20 nm and the film thickness of the Ti film of the intermediate layer was 10 nm.

[0050]

[Table 1]

	First embodiment	Second embodiment	Comparative Example
Half value width $\Delta\theta_{50}$ (degrees)	5.8	4.0	7.1

[0051]

As shown in Table 1, the respective half value widths $\Delta\theta_{50}$ of the magnetic disks manufactured in the first and second embodiments were smaller than the half value width $\Delta\theta_{50}$ =7.1 degrees of the magnetic recording medium manufactured in Comparative Example. That is, it has been revealed that the c-axis orientation of the recording layer formed of the CoPtCr alloy magnetic film containing oxygen is improved by using the CoCrRu film for the underlayer for

the recording layer.

[0052]

Subsequently, the magnetic disk manufactured in Comparative Example was installed into the magnetic recording apparatus 60 shown in Fig. 4 to evaluate the recording and reproduction characteristics in the same manner as in the first and second embodiments. However, the measurement was performed for the magnetic disk in which the film thickness of the Ru film of the underlayer was 20 nm. An obtained result is shown in Table 2. Table 2 also shows and summarizes the values of the S/N ratios obtained from the playback tests for the magnetic disks manufactured in the first and second embodiments. However, the S/N ratio of the Example 1 was a result obtained from a case in which the film thickness of the CoCrRu film of the underlayer was 20 nm, and the S/N ratio of the Example 2 was a result obtained from a case in which the film thickness of the CoCrRu film of the underlayer was 20 nm and the film thickness of the Ti film of the intermediate layer was 10 nm.

[0053]

[Table 2]

	First embodiment	Second embodiment	Comparative Example
S/N ratio (dB)	25	27	12

[0054]

As shown in Table 2, the S/N ratio of the magnetic disk of Comparative Example was 12 dB, while the obtained S/N ratios of the magnetic disks of the first and second embodiments were 25 dB and 27 dB respectively. The S/N ratios of the magnetic disks of the first and second embodiments were greatly improved as compared with the S/N ratio of the magnetic disk of Comparative Example. Therefore, it has been revealed that the S/N ratio is greatly improved by using the CoCrRu film as the underlayer for the recording layer formed of the CoPtCr alloy magnetic film which contains oxygen.

[0055]

The first and second embodiments have been explained as exemplified by the case in which the CoPtCr alloy magnetic film containing oxygen is used for the recording layer of the magnetic disk. However, the present invention is not limited thereto. The CoPtCr alloy magnetic film containing oxygen is crystalline, which has such a structure that the alloy containing the main component of Co exists in the crystal grains and the oxygen is contained between the grains. Therefore, the crystalline Co alloy may contain an element including, for example, Ta, Nb, Ti, Si, B, Pd, V, Mg and Gd or any combination thereof other than Cr and Pt.

[0056]

The first and second embodiments have been explained

as exemplified by the case in which the glass is used as the substrate material for the magnetic disk. However, the present invention is not limited thereto. It is also allowable to use, for example, aluminum, plastic such as polycarbonate, or resin.

[0057]

The first and second embodiments have been explained as exemplified by the case in which the CoTaZr film is provided as the soft magnetic back layer of the magnetic disk. However, the present invention is not limited thereto. The soft magnetic back layer may be made of other soft magnetic films generally known to be used for the perpendicular magnetic recording, for example, FeTaC, FeTaN, FeAlSi, FeC, CoB, CoTaNb, or NiFe. Alternatively, the soft magnetic back layer may be a stacked or laminated film composed of a C film and a soft magnetic film made of any one of the foregoing compounds.

[0058]

The first and second embodiments have been explained as exemplified by the case in which the content of oxygen in the recording layer is adjusted by using the target obtained by mixing oxygen in the CoPtCr alloy when the CoPtCr alloy magnetic film containing oxygen is formed as the recording layer. However, the present invention is not limited thereto. The content of oxygen in the recording layer may be adjusted by performing the sputtering by using

a mixed gas of oxygen and argon with a target containing no oxygen. Alternatively, the content of oxygen in the recording layer may be adjusted by performing the sputtering by using a mixed gas of oxygen and argon as the sputtering gas and using a target obtained by mixing oxygen in the CoPtCr alloy.

[0059]

The second embodiment is illustrative of the magnetic disk in which only one layer of the Ti film as the intermediate layer was provided between the soft magnetic back layer and the underlayer. However, the present invention is not limited thereto. The intermediate layer may be formed in a form of a plurality of layers.

[0060]

The second embodiment is illustrative of the magnetic disk in which the Ti film was used as the intermediate layer of the magnetic recording medium. However, the present invention is not limited thereto. The Ta film may be used as the intermediate layer, or an alloy mainly containing Ti or Ta may be used as the intermediate layer.

[0061]

The first and second embodiments are illustrative of the magnetic disk in which the underlayer and the recording layer are stacked on the substrate. However, the present invention is not limited thereto. When the underlayer itself has a function to support the recording layer, it is

allowable to provide no substrate in some cases.

[0062]

[EFFECTS OF THE INVENTION]

According to the magnetic recording medium of the present invention, the crystalline orientation of the recording layer is improved, the coercivity is enhanced, and the medium noise can be reduced by using the CoCrRu film as the underlayer for the recording layer formed of the CoPtCr alloy magnetic film containing oxygen. Accordingly, it is possible to provide the magnetic recording medium which has the high coercivity, which undergoes the low medium noise, and which makes it possible to perform the high density recording. Further, it is possible to provide the magnetic recording apparatus provided with the same. In addition, by providing the Ti film between the underlayer formed of the CoCrRu film and the soft magnetic back layer, it is possible to further improve the crystalline orientation of the recording layer, to reduce the medium noise, and to provide a magnetic recording medium which makes it possible to perform the higher density recording and a magnetic recording apparatus provided with the same.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[Fig. 1] Fig. 1 shows a schematic sectional view illustrating a magnetic disk according to a first embodiment.

[Fig. 2] Fig. 2 shows the changes of the perpendicular coercivity $Hc_{\perp}$ and the in-plane coercivity $Hc_{\parallel}$ of the magnetic disk with respect to the film thickness of a CoCrRu film as an underlayer of the magnetic disk of the first embodiment.

[Fig. 3] Fig. 3 shows a result of the X-ray diffraction measurement for the surface of the magnetic disk at a film thickness of 20 nm of the CoCrRu film as the underlayer of the magnetic disk of the first embodiment, wherein Fig. 3(a) is a graph showing the X-ray diffraction, and Fig. 3(b) shows a rocking curve measured at the peak of CoCrPtO (002).

[Fig. 4] Fig. 4 shows schematic views illustrating a magnetic recording apparatus provided with magnetic disks manufactured according to the present invention, wherein Fig. 4(a) shows a plan view, and Fig. 4(b) shows a sectional view taken along a line A-A' shown in Fig. 4(a).

[Fig. 5] Fig. 5 shows a schematic sectional view illustrating a magnetic disk according to a second embodiment.

[Fig. 6] Fig. 6 shows the change of the perpendicular coercivity $Hc_{\perp}$ of the magnetic disk with respect to the film thickness of a Ti film as an intermediate layer of the magnetic disk of the second embodiment.

[Fig. 7] Fig. 7 shows the relationship between the half value width $\Delta\theta_{50}$ of a rocking curve of the peak of

CoCrPtO (002) and the film thickness of the CoCrRu film in the magnetic disks manufactured in the second embodiment.

[EXPLANATION OF REFERENCE NUMERALS]

1 substrate

2 adhesive layer

3 soft magnetic back layer

4 underlayer

5 recording layer

6 protective layer

7 intermediate layer

10, 50 magnetic disk

60 magnetic recording apparatus

[TITLE OF THE DOCUMENT] Abstract

[ABSTRACT]

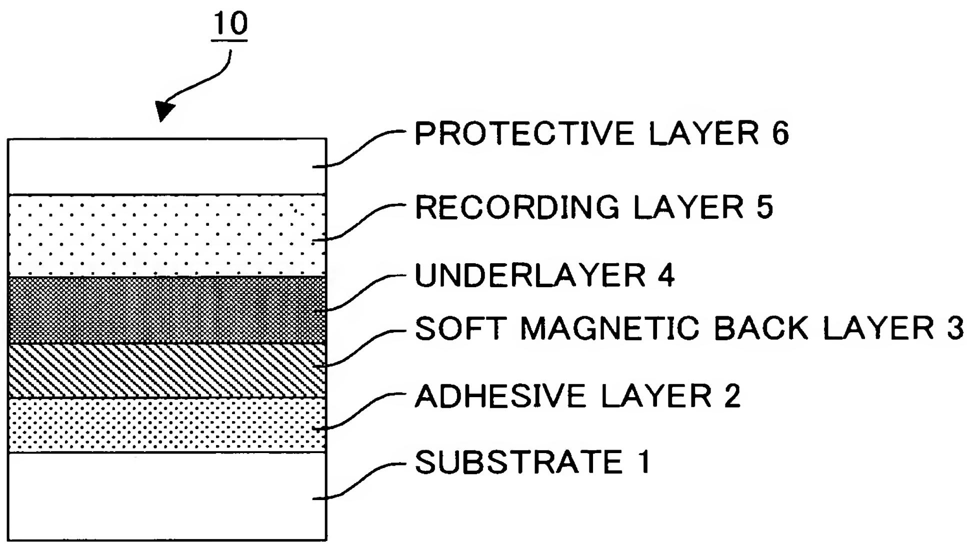
[PROBLEM TO BE SOLVED] To provide a magnetic recording medium based on the perpendicular recording system, which has high coercivity and low medium noise by using an underlayer which has a thin film thickness and which makes it possible to improve the orientation of a recording layer.

[MEANS TO SOLVE PROBLEMS] The magnetic recording medium based on the perpendicular recording system has the recording layer which is formed of a CoPtCr alloy magnetic film containing oxygen. The magnetic recording medium has such a structure that an adhesive layer 2, a soft magnetic back layer 3, the underlayer 4, the recording layer 5, and a protective layer 6 are successively stacked on a substrate 1. A CoCrRu film, which has a film thickness of 5 nm to 20 nm, is used as the underlayer for the recording layer formed of the CoPtCr alloy magnetic film containing oxygen. Thus, it is possible to improve the crystalline orientation of the recording layer with the underlayer having the thin film thickness.

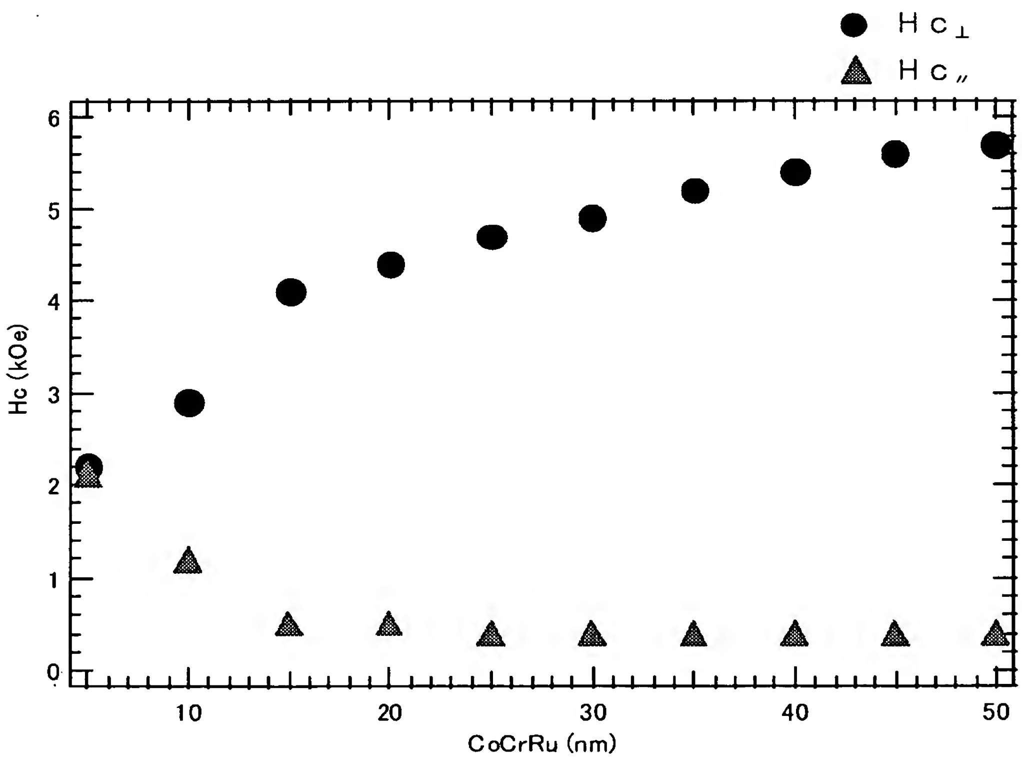
[SELECTED DRAWINGS] Fig. 1

[TITLE OF DOCUMENT] Drawings

[Fig. 1]

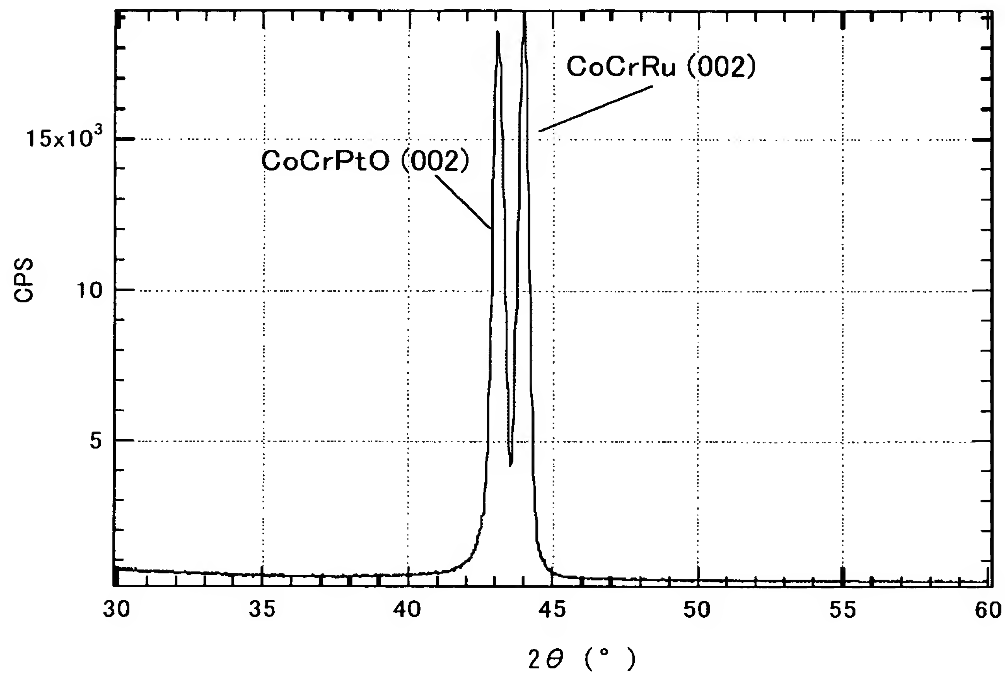


[Fig. 2]

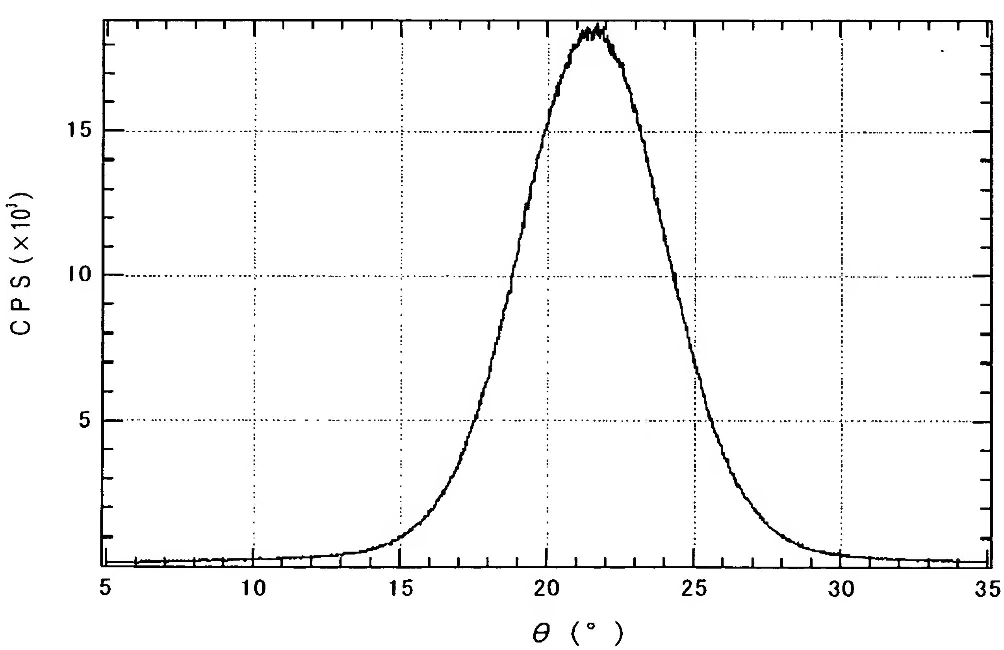


[Fig. 3]

(a)

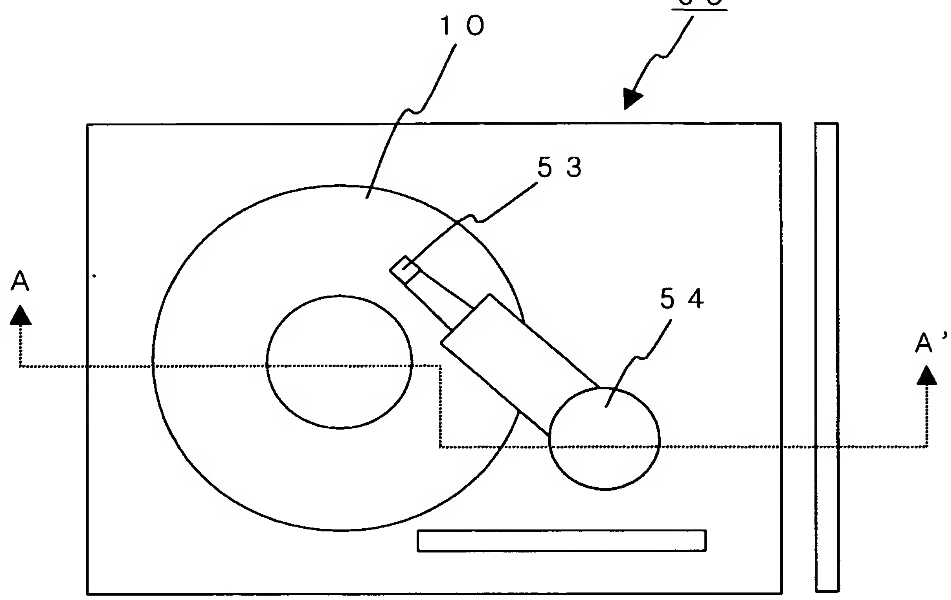

CoCrRu (002)
CoCrPtO (002)
15x10^3
10
5
CPS
30
35
40
45
50
55
60
2θ (°)

(b)

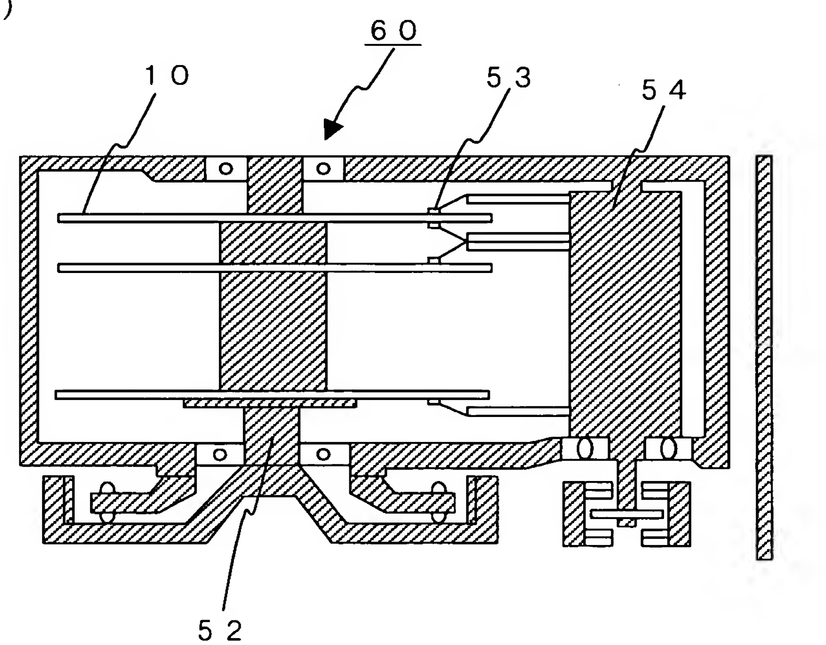

15
10
5
CPS (×10^3)
5
10
15
20
25
30
35
θ (°)

[Fig. 4]

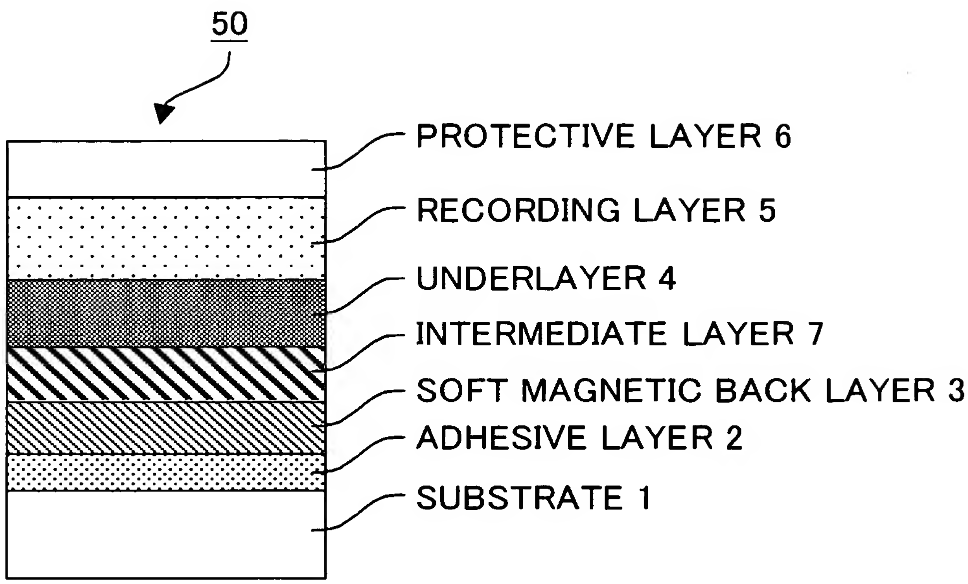
(a)



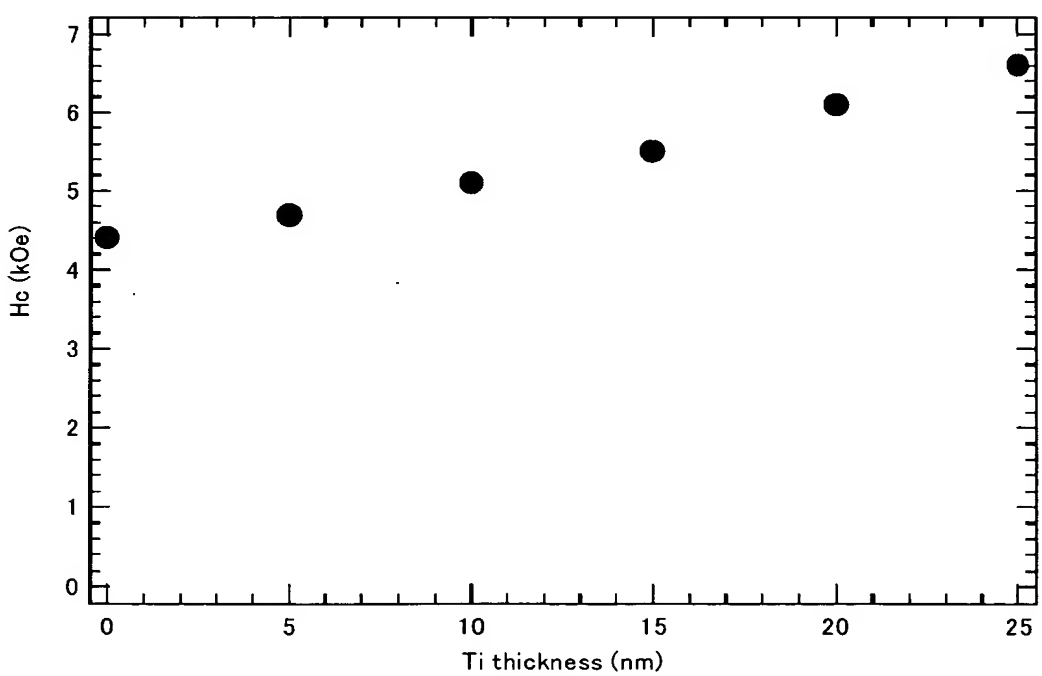
(b)



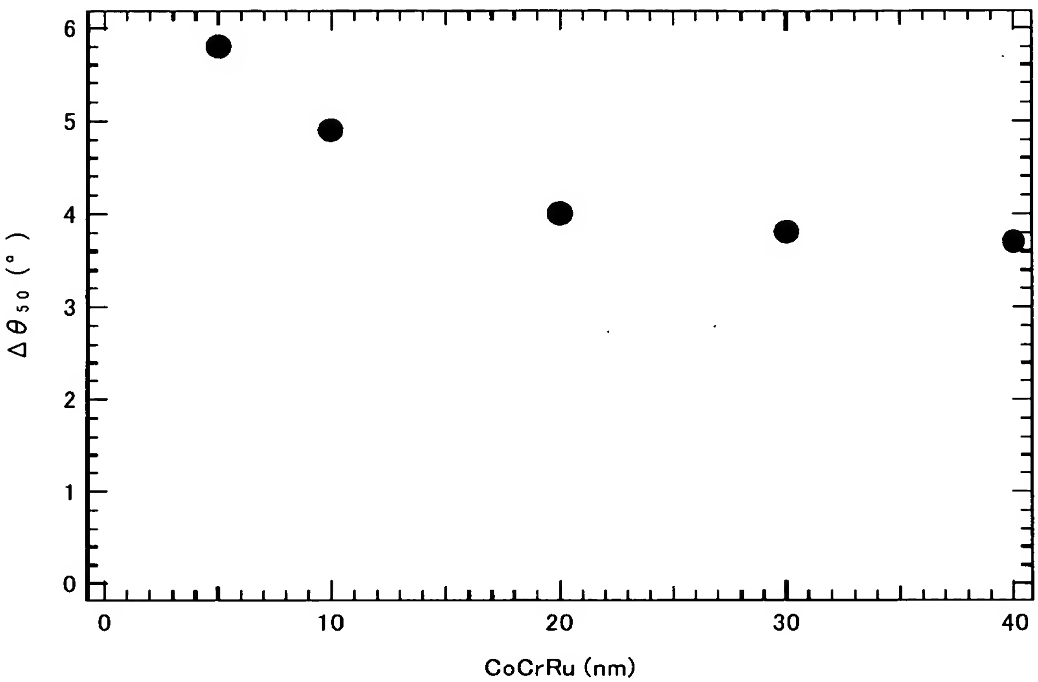
[Fig. 5]


50
PROTECTIVE LAYER 6
RECORDING LAYER 5
UNDERLAYER 4
INTERMEDIATE LAYER 7
SOFT MAGNETIC BACK LAYER 3
ADHESIVE LAYER 2
SUBSTRATE 1

[Fig. 6]


Hc (kOe)
0
1
2
3
4
5
6
7
0
5
10
15
20
25
Ti thickness (nm)

[Fig. 7]



INFORMATION ON APPLICANT'S HISTORY

Identified Number [000005810]

1.	Date of change	August 29, 1990
	[Reason for change]	New registration
	Address	1-88, Ushitora 1-chome, Ibaraki-shi, Osaka
	Name	HITACHI MAXELL, LTD.
2.	Date of change	June 10, 2002
	[Reason for change]	Change of address
	Address	1-88, Ushitora 1-chome, Ibaraki-shi, Osaka
	Name	HITACHI MAXELL, LTD.